
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

NASA-16365 (June 2004)
NASA
Superseding NASA-16365
(March 2003)

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SECTION 16365

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SECTION 16365

PRIMARY UNIT SUBSTATION
06/04

NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers 5-kilovolt to 15-kilovolt primary-unit substations including incoming, transformer, and outgoing sections, which provide in each instance for the connection of one or more incoming line circuits, one or more transformers, and one or more outgoing feeder circuits.

Drawings should include the following:

Location of the substation on the electrical site plan

Details of substation incoming, outgoing, and transformer sections in plan and elevation

Electrical one-line riser diagram indicating the electrical interconnections and voltage characteristics of incoming and outgoing line and feeder circuits and the electrical characteristics of all component equipment

PART 1 GENERAL

1.1 REFERENCES

NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

The publications listed below form a part of this section to the extent referenced:

AMERICAN IRON AND STEEL INSTITUTE (AISI)

AISI SG-671

(1989) Specification & Commentary for the

Design of Cold-Formed Steel Structural
Members

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

| | |
|----------------|---|
| ANSI C29.10 | (1989; R 1995) Wet-Process Porcelain Insulators - Indoor Apparatus Type |
| ANSI C37.121 | (1989; R 2000) American National Standard for Switchgear-Unit Substation-Requirements |
| ANSI C57.12.10 | (1997) Standard for Transformers-230 kV and Below 833/958 Through 8333/10,417 kVA, Single-Phase, and 750/862 Through 60,000/80,000/100,000 kVA, Three-Phase Without Load Tap Changing; and 3750/4687 Through 60,000/80,000/100,000 kVA With Load Tap Changing - Safety Requirements |
| ANSI C57.12.40 | (2000) Subway and Vault Types (Liquid Immersed) - Requirements |
| ANSI C57.99 | (1965) Guide for Loading Dry-Type and Oil-Immersed Current-Limiting Reactors Appendix to American Standard Requirements Terminology, and Test Code for Current-Limiting Reactors C57.16-1958 |

ASTM INTERNATIONAL (ASTM)

| | |
|-------------------|---|
| ASTM A 345 | (1998) Standard Specification for Flat-Rolled Electrical Steels for Magnetic Applications |
| ASTM A 36/A 36M | (2003a) Standard Specification for Carbon Structural Steel |
| ASTM A 366/A 366M | (1997e1) Standard Specification for Steel, Sheet, Carbon, Cold-Rolled, Commercial Quality |
| ASTM A 570/A 570M | (1998) Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality |
| ASTM B 48 | (2000) Standard Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors |
| ASTM D 117 | (2002) Standard Guide for Sampling, Test Methods, Specifications and Guide for Electrical Insulating Oils of Petroleum Origin |
| ASTM D 1533 | (2000) Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration |
| ASTM D 3487 | (2000) Standard Specification for Mineral |

Insulating Oil Used in Electrical Apparatus

| | |
|-------------|---|
| ASTM D 3612 | (2002) Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography |
| ASTM D 877 | (2002) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes |
| ASTM D 92 | (2002b) Standard Test Method for Flash and Fire Points by Cleveland Open Cup |
| ASTM D 924 | (1999) Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids |
| ASTM D 974 | (1997) Standard Test Method for Acid and Base Number by Color-Indicator Titration |

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

| | |
|----------------|--|
| ANSI C57.19.01 | (2000) General Requirements and Test Procedure for Outdoor Power Apparatus Bushings |
| IEEE C2 | (2002) National Electrical Safety Code |
| IEEE C37.20.1 | (2002) Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear |
| IEEE C37.20.2 | (1999) Metal-Clad and Station-Type Cubicle Switchgear |
| IEEE C37.35 | (1995) Guide for the Application, Installation, Operation, and Maintenance of High-Voltage Air Disconnecting and Load Interrupter Switches |
| IEEE C57.12.00 | (2000) Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers |
| IEEE C57.12.80 | (2002) Standard Terminology for Power and Distribution Transformers |
| IEEE C57.12.90 | (1999) Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers |
| IEEE Std 32 | (1972; R 1991) Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Devices |
| IEEE Std 4 | (1995) Standard Techniques for High Voltage Testing |

IEEE Std 48 (1996; R 2003) Standard Test Procedures and Requirements High-Voltage Alternating-Current Cable Terminations 2.5 kV through 765 kV

IEEE Std 62 ((1995) Guide for Diagnostic Field Testing of Electric Power Apparatus-Part 1: Oil Filled Power Transformers, Regulators, and Reactors

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2002) National Electrical Code

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS FF-H-106 (1974c) Hardware, Builders'; Locks and Door Trim: General Specification for

UNDERWRITERS LABORATORIES (UL)

UL 1062 (2001) UL Standard for Safety Unit Substations

UL 467 (2001) UL Standard for Safety Grounding and Bonding Equipment

1.2 GENERAL REQUIREMENTS

NOTE: If Section 16003, "General Electrical Provisions," is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.

Section 16003, "General Electrical Provisions," applies to work specified in this section.

Connection Diagrams shall be submitted indicating the relations and connections of the following items by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

Certificates of Compliance shall be submitted for Primary Unit Substations including the following:

Certificates of conformance verifying that the materials and structural design comply with the roof live load, floor live load, and wind pressures specified under the paragraph entitled, "Weatherproof Enclosures with Maintenance Aisles," of this section.

In lieu of factory tests on actual units furnished, certified copies of previous tests on similar units under actual conditions, not simulated, may be submitted for impulse tests, temperature rise tests, sound tests, bushing tests, and short circuit tests.

Certified evidence of the qualifications of the system

coordination specialist shall be submitted.

Equipment Foundation Data for primary unit substations shall include plan dimensions of foundations and relative elevations, equipment weight and operating loads, horizontal and vertical loads, horizontal and vertical clearances for installation, and size and location of anchor bolts.

Manufacturer's Standard Color Charts shall be submitted for primary unit substations showing the manufacturer's recommended color and finish selections.

1.3 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01330, "Submittals," and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

The following shall be submitted in accordance with Section 01330, "Submittals," in sufficient detail to show full compliance with the specification:

SD-02 Shop Drawings

Connection Diagrams shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

Incoming Sections
Transformer Sections
Outgoing Sections
Switchgear Components

Fabrication drawings shall be submitted for the following items consisting of fabrication and assembly details to be performed in the factory.

Incoming Sections
Transformer Sections
Transformer Tanks
Bushings
Transformer Cores
Transformer Coils
Outgoing Sections
Switchgear Components
Post Bushings
Accessories

Installation Drawings shall be submitted for the primary unit substation in accordance with the paragraph entitled, "Installation," of this section.

SD-03 Product Data

Equipment and performance data shall be submitted for the following items including life, test, system functional flows, safety features, and mechanical automated details.

- Incoming Sections
- Transformer Sections
- Outgoing Sections
- Switchgear Components
- Post Bushings
- Automatic Transfer Switch Operation and Devices
- Weatherproof Enclosures

Equipment Foundation Data shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

Manufacturer's catalog data shall be submitted for the following items:

- Incoming Sections
- Transformer Sections
- Transformer Tanks
- Bushings
- Transformer Cores
- Transformer Coils
- Outgoing Sections
- Switchgear Components
- Post Bushings
- Automatic Transfer Switch Operation and Devices
- Weatherproof Enclosures
- Paint Materials

SD-04 Samples

Manufacturer's Standard Color Charts shall be submitted for primary unit in accordance with paragraph entitled, "General Requirements," of this section.

SD-06 Test Reports

Test reports shall be submitted for the following tests on primary unit substations in accordance with the paragraphs entitled, "Factory Testing" and "Relay Settings and Tests," of this section.

- Pressure Tests
- Ratio Tests
- Rotation Tests
- Impedance Voltage Load Loss Tests
- Dielectric Tests
- Operational Test
- Continuity Tests
- Insulation-Resistance Tests
- Insulation Power Factor Tests
- Oil Power Factor Tests
- Oil Acidity Tests
- Water-in-oil (Karl Fischer) Tests
- Dissolved Gas Analysis
- Sound Tests
- Impulse Tests
- Short Circuit Test

Bushing Tests

SD-07 Certificates

Certificates of Compliance shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals shall be submitted for the following equipment:

- Switchgear Assemblies
- Surge Arresters
- Station Battery
- Transfer Switches
- Space Heaters

1.4 QUALIFICATIONS FOR MANUFACTURERS

Material and equipment to be provided under this specification shall be the standard catalog product of a manufacturer regularly engaged in the manufacture of primary unit substations and their component parts and equipment. Equipment shall be of the latest standard design for outdoor service and shall have been in repetitive manufacture for at least 150 units.

Qualification tests for transformers shall conform to Section 16276, "Medium Voltage Transformers."

Qualification tests for circuit breakers shall conform to Section 16286, "Overcurrent Protection Devices."

1.5 SYSTEM COORDINATION AND TESTING SERVICES

System coordination studies, relay settings, and tests shall be performed by a professional electrical engineer who can present evidence of at least [5] [_____] years experience in system coordination and tests of the kind specified in not less than five projects of comparable size and complexity. Work shall be done by or under the direct supervision of this specialist. Personnel working pursuant to this section, may at the Contracting Officer's option, be required to demonstrate technical competence by performing sample work [and/or by displaying their state qualifications/certificates], at no additional cost to the Government.

1.6 DELIVERY, STORAGE AND HANDLING

Subassemblies of articulated primary unit substations shall be delivered, stored, handled, and installed in a manner that will not damage the equipment. Equipment shall be stored in the original unbroken protective covering and shipping container, indoors, in a clean, dry, and ventilated location.

During installation, equipment shall be protected from the weather.

PART 2 PRODUCTS

2.1 EQUIPMENT STANDARDS

Primary unit substations shall conform to UL 1062 and ANSI C37.121.

2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Ratings

Incoming section shall be rated [7,200] [13,800] [35,000] volts for connection to [6,900] [13,200] [34,000]-volt, three-phase, 60-hertz, [grounded] [ungrounded] power-distribution systems.

Transformer shall be [_____] kVA, [_____] volt, with a [delta] [_____] primary winding and a [grounded wye] [_____] secondary winding.

Outgoing section shall be rated [4,160] [7,200] [13,800] volts for connection to [2,300] [6,900] [13,200]-volt, three-phase, 60-hertz, [grounded] [ungrounded] power-distribution systems.

2.2.2 Insulation Class

Transformer secondary windings shall be insulated for [5,000] [8,660] [15,000] volts for connection to [2,300] [6,900] [13,200]-volt, three-phase, 60-hertz, power-distribution systems.

Transformer primary windings shall be insulated for [8,660] [15,000] [35,1000] volts for connection to [6,900] [13,200] [34,000]-volt, three-phase, 60-hertz, power-distribution systems.

2.2.3 Basic-Impulse Insulation Levels

Basic-impulse insulation levels of the incoming, transforming, and outgoing sections of complete primary unit substations shall be in accordance with UL 1062.

2.3 INCOMING SECTIONS

NOTE: Delete the title, subtitles, and all text under "Incoming Section" when the incoming line or lines terminate in cable-terminating boxes or load-break oil switches specified in the transformer section.

2.3.1 Switchgear and Auxiliary Equipment Compartments

Switchgear and auxiliary equipment compartments for the incoming section shall conform to the requirements specified for the switchgear and auxiliary equipment compartments for the outgoing section.

2.3.2 Switchgear Assemblies

General arrangement of the incoming section, the number of compartments, and each compartment's components shall be as shown.

[Incoming-line switchgear compartments shall include the following:

Metal-clad air circuit breaker, oil circuit breaker, fused disconnect switch, and control switch

Current transformers, ammeter, and ammeter switch

Overcurrent and ground-fault relays

Voltmeter and voltmeter switch

Undervoltage relays

Key interlock between primary [switch] [circuit breaker] and secondary [switch] [circuit breaker]

wattmeter

Draw-out type potential transformers with fuse protection

Lightning arresters three-station type

Pothead for terminating PILCN cables, [paper-insulated, lead-jacketed copper, neoprene cable]

Provision for terminating cables single feeder loop/dual feed

Space heaters]

[Auxiliary compartment for the control of two incoming lines shall include the following:

Potential transformers for incoming lines

Potential transformers for metering purposes

Reverse-current directional relays

Undervoltage and phase rotation relays

Auxiliary compartment for control-power transformer and primary fuses

Auxiliary compartment for batteries and battery chargers]

[Auxiliary compartment for totalized metering and ground detection shall include the following:

Potential transformers for ground detection

Potential transformers for metering purposes

Voltmeters for ground detection

Totalizing watt-hour graphic demand meter or wattmeter for special metering only]

[Transformer primary switchgear compartment shall include the following:

Metal-clad air circuit breaker and control switch

Current transformers, ammeters, and ammeter switches

Overcurrent reclosing relays and reverse-current directional relays

Provision for terminating cables]

[Primary feeder switchgear compartments shall include the following:

Metal-clad air interrupter switch, oil circuit breaker, fused disconnect switch

Surge protectors, lightning arresters

Fuses, three

Provision for terminating cables loop single feed]

[Transformer primary incoming switchgear compartments shall include the following:

Load-break oil, Air, or Vacuum Switch

Surge protectors, lightning arresters

Provision for terminating cables]

[Incoming line bus entrance compartment shall include an insulated rigid copper bus for direct connection of the incoming line to the main bus, with provision for terminating cables. Rigid copper bus shall be supported to withstand a 50,000-ampere rms short circuit and shall be rated for 65 degrees C temperature rise.]

[Auxiliary transition compartment shall include an insulated rigid copper bus for direct connection of adjacent auxiliary or switchgear compartments to the throat of the transformer section. Rigid copper bus shall be supported to withstand a 50,000-ampere rms short circuit and shall be rated for 65 degrees C temperature rise.]

Underfloor and inside roof section of the switchgear shall be undercoated with a [heavy plastic] [rubberized] protective sealing material at least 1/32-inch 0.8 millimeter thick. Sealing material containing asbestos shall not be used.

2.4 TRANSFORMER SECTIONS

2.4.1 Transformers

Transformer in the transformer section of primary unit substations shall be two-winding, three-phase, 60-hertz, oil-immersed, 65-degree C rise, self-cooled, Class OA or Class OA/FA forced-air cooling, outdoor-type conforming to the following standards: IEEE C57.12.00, ANSI C57.12.10, IEEE C57.12.80. Primary windings of the transformer shall be [delta] [wye] connected.

Transformers shall include a core-and-coil assembly enclosed in a sealed, airtight and oiltight tank with accessories and auxiliary equipment.

Core shall be built up with laminated, nonaging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Laminations shall be

coated with an insulating film or finish to minimize eddy-current losses. Sheet steel shall conform to ASTM A 345.

NOTE: For transformers to be installed in high fault current areas aluminum and sheet windings should be avoided. Aluminum has 1/3 the mechanical strength of copper and will deform at 300 degrees C (temperatures in excess of 300 degrees can easily occur in faults over 4000 amps). Additionally, sheet windings lack sufficient mechanical strength to survive fault currents above 4000 amps symmetrical.

High- and low-voltage coil sections shall consist of insulated [copper] [aluminum] conductors wound around the core. Coil sections shall be concentric to counteract forces incurred under short-circuit conditions and shall be provided with oil ducts to dissipate the heat generated in the windings. Coil sections shall be electrically connected together and to the respective terminal bushings of the transformer. Copper conductors in the high- and low-voltage coil sections shall conform to ASTM B 48, Type B for applications involving edgewise bending.

Complete assembly shall be capable of withstanding an earthquake lateral force equivalent to a horizontal acceleration of 40 percent of gravity.

Walls, bottom, and cover of the transformer tank shall be fabricated from hot-rolled steel plate, with cooling tubes or radiators vertically mounted to the side walls of the tank. Transformer tank shall be welded construction with a base designed for using rollers or skidding in any direction. Tank shall have a manhole or handholes.

Transformer base shall be designed to provide natural draft ventilation under the transformer tank when the transformer is installed on the concrete foundation. Bottom of the transformer shall be undercoated with a heavy rubberized protective sealing material at least 1/32-inch 0.8 millimeter thick. Sealing material containing asbestos shall not be used.

[Cooling tubes shall be welded into headers which in turn shall be welded into the transformer tank wall.]

[Radiators shall be detachable all-welded construction with top and bottom connections to the transformer tank wall. Tank wall top and bottom connections to radiators shall be equipped with valves that will permit removal of the radiator without draining oil from the transformer tank.]

Lifting, moving, and jacking facilities conforming to ANSI C57.12.10 shall be provided.

[A sealed-tank oil-preservation system shall be provided, to seal the interior of the transformer from the atmosphere throughout a top oil temperature range to 100 degrees C. Gas and oil volume shall remain constant with the internal gas pressure not exceeding 10 pounds per square inch, gage (psig) 69 kilopascal positive or 8 psig 55 kilopascal negative. Provision shall be made for the relief of excessive internal pressure in the transformer tank.]

[An inert gas-pressure oil-preservation system shall be provided to seal

the interior of the transformer from the atmosphere throughout a top oil temperature range to 100 degrees C with the internal gas pressure not exceeding 8 psig 55 kilopascal. Gas shall be dry inert nitrogen which shall be maintained under positive pressure from a separate inert gas source and reducing valve system. System shall include a pressure/vacuum gage, pressure/vacuum relief valve, initial cylinder of gas, and gas sampling and purging valve to provide fully automatic control of the gas pressure. Normally open alarm contacts rated 250 volts, direct current that will close under low pressure, high pressure, and low cylinder-gas supply conditions shall be provided.]

[Tank shall have a manhole in the cover. Circular manholes shall not be less than 15 inches 390 millimeter in diameter. Rectangular or oval manholes shall not be less than 10 by 16 inches 260 by 410 millimeter.]

[Tank shall have a handhole in the cover. Circular handholes shall not be less than 9 inches 230 millimeter in diameter. Rectangular handholes shall not be less than 4-1/2-inches 115 millimeter wide and shall have an area of not less than 65 square inches 42,000 square millimeter.]

Transformer sound level in decibels (dB) shall not exceed [65 dB] [the following values:

| <u>RATED kVA</u> | <u>WITHOUT FANS</u> | <u>WITH FANS</u> |
|------------------|---------------------|------------------|
| 500 | 56 dB | 67 dB |
| 1,000 | 58 dB | 67 dB |
| 2,500 | 62 dB | 67 dB] |

Completely assembled transformer shall be designed to withstand, without permanent deformation, a pressure 25-percent greater than the maximum operating pressure of the sealed tank oil preservation system.

Transformers shall be provided with throats or flanges for the enclosure of side-wall bushings and their connections to the incoming and outgoing sections of the unit substation, as required. Secondary neutral of the transformer shall be brought out through the wall of the tank into the secondary throat with a bushing identical to the secondary line bushings. All bushings shall have copper current carrying conductors.

One set of spare mounting gaskets shall be provided for bushings, handholes, and the gasket between the relief cover and flange on the mechanical relief device.

[Transformer shall be equipped with automatically controlled fans to provide forced-air-cooled transformer ratings in accordance with ANSI C57.12.10. Equipment shall include a thermally operated control device, manually operated bypass switch, motor-driven fans, and electrical conduit and wire connections. Thermally operated control device shall consist of a top oil temperature relay with the thermal element mounted in a well responsive to the top liquid level temperature of the transformer. Well shall conform to IEEE C57.12.00. Manually operated bypass switch shall be connected in parallel with the automatic control contacts and enclosed in a weatherproof cabinet located on the side of the transformer at a height not greater than 60 inches 1600 millimeter above the concrete foundation. Fan motors shall be 230 volts, single-phase, 60-hertz, without a centrifugal switch and shall be individually fused or thermally protected.]

[Provision shall be made for the future installation of automatically controlled, motor-driven fans to give forced-air-cooled transformer ratings conforming to ANSI C57.12.10. Necessary mechanical arrangements shall be provided for a control as described in IEEE C57.12.00. Provision shall be made for the future mounting of control cabinets, conduit, and fans.]

Transformer accessories shall include a liquid-level indicator, liquid-temperature indicator, pressure/vacuum gage, drain and filter valves, ground pads, and identification plate. Transformer accessories and their locations shall conform to ANSI C57.12.10.

Transformer kilovolt-ampere (kVA) ratings are continuous and shall be based on temperature rise. Temperature limits shall not be exceeded when the transformer is delivering the rated kVA output at rated secondary voltage, with or without tap connections in accordance with IEEE C57.12.00.

Percent impedance voltage at the self-cooled rating shall be in accordance with ANSI C57.12.10.

Insulating oil shall conform to ASTM D 3487 with inhibitor. Dielectric strength of transformer oils when shipped shall not be less than 28 kV, when measured in accordance with ASTM D 117. Neutralization Number shall not be greater than .03 gm KOH/ml when measured in accordance with ASTM D 974. Emulsified water shall not exceed 25 ppm at 20 degrees C, when measured in accordance with ASTM D 1533. Power factor shall not exceed 0.5 percent at 20 degrees C when measured in accordance with ASTM D 924. The manufacturer shall certify that the oil contains no PCB's and shall affix a label to that effect on the transformer tank and on each oil drum containing the insulating oil.

Insulating liquid other than oil shall be a nonpropagating liquid having a fire point not less than 300 degrees C. Liquid shall have been tested for flash point in accordance with ASTM D 92 and for dielectric strength of not less than 33 kV in accordance with ASTM D 877.

Transformers shall be capable of withstanding, without injury, the mechanical and thermal stresses caused by short circuits on the external terminals of the low-voltage windings, in accordance with IEEE C57.12.00.

**NOTE: Delete the following paragraph when automatic
tap changers are specified.**

Primary winding of the transformer shall be equipped with four 2.5-percent full capacity taps, two above and two below normal voltage, brought out to an externally operated manual tap changer. Tap changer handle shall be capable of being padlocked in each tap position and shall be operated only when the transformer is deenergized.

2.4.2 Automatic Load Tap Changers

Transformer shall be equipped with three-phase automatic load tap changing equipment that will provide 10-percent voltage adjustment in 16 equal steps above and below the rated secondary voltage in accordance with ANSI C57.12.10.

Load tap changing equipment shall consist of an arcing-tap switch or tap

selector and arcing switch, a motor-driving mechanism, position indicator, and automatic control devices contained in weatherproof enclosures mounted on the side walls of the transformer tank.

Arcing tap switch or tap selector and arcing switch shall be located in one or more oil-immersed, welded steel-plate compartments with removable bolted external access covers, drain and sampling valve, filling plug, and magnetic liquid-level gage. Provision shall be made for the escape of gas generated by the arcing contacts. Oil in the arcing switch compartment shall be isolated from the oil in the transformer tank.

Motor-drive mechanism shall be equipped with a 230-volt, single-phase, 60-hertz motor and handcrank or hand wheel for automatic manual operation of the driving mechanism. Mechanically operated electrical limit switches shall be provided to prevent overtravel beyond the maximum lower and raise positions.

Automatic control devices shall be housed in a weatherproof sheet metal cabinet with a breather and hinged doors to provide access to the control devices. Provision shall be made for padlocks.

Automatic control devices shall include a voltage-regulating relay, time delay, manual/automatic selector switch, line-drop compensator, paralleling switch, current transformers, reactance/reversal control switch, operation counter, current and potential test terminals, lampholder and switch, heater and switch, convenience outlet, and protective devices in accordance with ANSI C57.12.10 and Section 16286, "Overcurrent Protective Devices."

Provision shall be made for the accurate alignment, positioning, and locking of arcing contacts in each tap position. When the load tap changing equipment is on a tap position at or above the rated secondary voltage, the transformer shall be capable of supplying its rated kVA. When the load tap changing equipment is on a tap position below the rated secondary voltage, the transformer shall be capable of supplying its rated current.

Voltage for the voltage-regulating relay shall be obtained from a potential transformer in the outgoing section. Power required to drive the mechanism shall be obtained from the control power transformer in the outgoing section.

2.4.3 Transformer Cable-Terminating Boxes

Transformer cable terminating box shall be a removable, weatherproof, nonsubmersible, air-filled compartment enclosing the side wall bushings of the transformer and equipped with mounting flanges to accommodate single-or multiple-conductor potheads or entrance fittings for a bottom connection to underground power cables. Enclosure shall be constructed of welded steel plate with bolted and gasketed flange connections and covers. Exposed bolts, nuts, and studs shall be silicon-bronze or corrosion-resistant steel.

Sealed cable-entrance fittings shall be cast brass with wiping sleeves for lead-covered cables and cast iron watertight stuffing boxes for nonleaded cables. Potheads shall be suitable for single- or multiple-conductor cables as required.

Transformer compartment flange openings and mounting plates for three-phase cable circuits shall conform to ANSI C57.12.10.

Electrical clearances and the dielectric test levels for potheads shall conform to ANSI C57.12.10.

Transformer cable-terminating boxes shall accommodate power cables up to and including 500 MCM a diameter of 17.9 millimeter (500 kemil) in size.

2.4.4 Metal-Enclosed Bus

NOTE: This bus is for the transformer secondary transition section.

Metal-enclosed bus shall be nonsegregated group phase construction and shall include rigid insulated conductors and supports in a grounded metal enclosure with associated ventilation and space-heater enclosures, condensation barriers, expansion and connection joints, and fittings in accordance with IEEE C37.20.1.

Enclosures shall be completely bused with an insulated solid rigid copper bus bar of rectangular cross section. Bus bar and connections shall be uniformly positioned and phase sequenced within the enclosure for adaptation to metal-clad switchgear assemblies and power transformers, in accordance with IEEE C37.20.1.

Bus bar shall be supported and braced to withstand short-circuit stresses with momentary current ratings, in accordance with IEEE C37.20.1. Contact surfaces of all bus connections shall be silver plated and bolted together to ensure maximum conductivity. Voltage and current ratings shall conform to IEEE C37.20.1.

Insulating supports shall consist of track-resistant, flame-retardant IEEE Class 130 electrical insulating materials. Voltage rating and insulation level shall conform to IEEE C37.20.1.

Sheet metal weatherproof enclosures shall be constructed from carbon steel sheets of commercial quality, not less than 14 gage 1.9 millimeter. Each section shall be reinforced with structural members and bolted together. Complete assembly shall be structurally supported as indicated.

Temperature limits for a metal-enclosed bus shall conform to IEEE C37.20.1.

2.5 OUTGOING SECTIONS

2.5.1 Switchgear and Auxiliary Equipment Compartments

NOTE: Ability to remove access covers is required for maintenance activities. In addition, access may be required to inspect these devices while circuits are energized (for example, using infrared imaging). Minimum distances to energized circuits is specified in OSHA Standards Part 1910.333 (Electrical - Safety-Related work practices). OSHA Standards are available on the internet.

Switchgear and auxiliary equipment of the outgoing section shall be a metal-clad switchgear assembly in an enclosed self-contained,

self-supporting, outdoor ventilated unit with sheet metal compartments joined together to form a continuous structure with front-hinged panels and [hinged] rear covers.

Barriers between adjacent compartments and the major components of each circuit within a compartment shall be sheet steel not less than 11 gage 3.1 millimeter. Other covers, barriers, panels, and doors shall not be less than 14 gage 1.9 millimeter.

Sheet metal barriers and enclosures shall be constructed from cold-rolled carbon-steel sheets of commercial quality with stretcher-level flatness conforming to ASTM A 366/A 366M. Each compartment shall be reinforced with structural members and welded together. Welds shall be ground to a smooth flat surface before painting.

Removable elements of the same type and rating in the switchgear assembly shall be physically and electrically interchangeable in corresponding compartments.

Front-hinged panel shall be suitable for mounting instruments, relays, control switches, and indicating lamps.

Compartments shall be completely bused with insulated rigid copper solid bus bar of rectangular cross section. Main buses and bus-tap connections shall be uniformly positioned and phase sequenced in accordance with IEEE C37.20.1.

Buses shall be supported and braced to withstand the maximum short-circuit stresses that would be incurred under the most severe fault conditions. Contact surfaces of all main bus and tap connections shall be silver plated and bolted together to ensure maximum conductivity.

Main bus shall be readily accessible for connection of future switchgear assemblies at either end.

Voltage rating and insulation level of switchgear assemblies shall conform to IEEE C37.20.1.

Temperature limits for insulating materials used in switchgear assemblies shall conform to IEEE C37.20.1.

Temperature limits for buses and bus-tap connections in switchgear assemblies shall be in accordance with IEEE C37.20.1.

A continuous rigid copper ground bus shall extend throughout the entire outgoing-line section and shall ground the stationary structure and equipment. Ground bus shall be capable of carrying the maximum rated short-circuit current of the protective device in the switchgear assembly for a minimum period of 1.0 second.

Compartments shall be provided with indicating lights identifying the breaker position, "OPEN/CLOSED." Indicating lights shall be supplied from the station control bus at 120 volts ac.

Low-voltage wiring for controls and accessories shall be run to terminal blocks having numbered points to identify all circuits. Low-voltage wiring shall be run in conduit, sheet metal compartments, or wireways to isolate the wiring from high-voltage circuits.

Each compartment of the switchgear assembly shall be identified with the manufacturer's standard identification plate engraved with circuit and function designations. Compartments shall be completely wired with cable terminals, cable clamps, control bus, control power switch, and terminal blocks. Terminal blocks shall be readily accessible for the external connections of metal-clad switchgear.

Sealed cable-entrance fittings shall be cast brass with wiping sleeves for lead-covered cables and shall be bolted to the bottom of the cable terminating compartment. Bottom of the wiping sleeves shall not be less than 30-inches 800 millimeter above the transformer foundation.

Entire assembly shall be watertight, oiltight, and airtight and shall be suitable for operation under extreme ambient weather conditions. Pressure tests shall be performed on switch tanks under water by the manufacturer after assembly and before delivery by applying an air pressure of 5 psi 34 kilopascal for 15 minutes. Switch tanks shall be pressure tested after installation and before filling with oil, by applying an air pressure of 5 psi 34 kilopascal for 15 minutes and visually checking for leaks by applying soapy water to all joints.

2.5.2 Switchgear Assemblies

General arrangement of the outgoing section, the number of compartments, and each compartment's components shall be as indicated.

Wiring to interior devices, contacts, coils, and other components shall be brought to an accessible terminal board for each compartment. Interior wiring shall be between terminal boards. Conductors shall be identified with a code system defining the compartment and device number.

[Auxiliary station power compartments shall include the following:

Contactor for automatic transfer of control power

Potential transformers for relaying purposes

Control-power transformer and primary fuses

Batteries and battery charger

Ground detector devices

Storage space for service and maintenance devices]

[Transformer secondary switchgear compartments shall include the following equipment:

Metal-clad air circuit breaker and control switch

Potential transformers

Current transformers, ammeters, and ammeter switch

Undervoltage relays

Overcurrent relays

Reverse current directional relays]

[Bus-sectionalizing switchgear compartments shall include the following equipment:

- Metal-clad air circuit breaker and control switch
- Undervoltage and phase rotation relays
- Automatic/manual transfer switch
- Kirk key interlocks
- Contactor for automatic transfer of control power]

[Secondary-feeder switchgear compartments shall include the following equipment and facilities:

- Metal-clad air circuit breaker and control switch
- Current transformers, ammeter, and ammeter switch
- Overcurrent relays
- Reclosing relays
- Provision for terminating cables]

[Current-limiting reactor compartments shall include the following equipment:

- Current-limiting air-core reactors
- Insulated bus with seal-off bushings
- Phase-bus connections to reactors]

[Neutral grounding-resistor compartments shall include the following equipment:

- Grid resistor elements
- Insulated bus with phase-bus connections
- Neutral bus and ground connections to grounding resistors]

[Motor-starter compartment shall include the following equipment and facilities:

- Metal-clad three-phase across-the-line motor starter
- Overcurrent protection in each phase
- Current limiting fuses
- Undervoltage and single-phase protection
- Exterior disconnect with indicating lamps
- Provision for cable terminations]

2.6 SWITCHGEAR COMPONENTS

2.6.1 Air Circuit Breakers and Air Interrupter Switches

2.6.1.1 Air Circuit Breakers

Air circuit breakers shall be of the solenoid-operated or stored-energy-operated type as indicated and shall conform to the applicable requirements of Section 16286, "Overcurrent Protective Devices."

2.6.1.2 Air Interrupter Switches

Air interrupter switches shall be the manually group-operated three-pole, gang-operated stationary type in accordance with part 5E of IEEE C37.35 and IEEE C37.20.1, and switch shall carry the rated current continuously.

Operating mechanism shall be quick-make/quick-break with positive fault closing and load-interrupting capability. Handle speed shall be independent of switch operation. Interrupter switch shall be capable of interrupting the magnetizing current of the transformer in the transformer section.

Operator shall be the stored energy type, designed for easy inspection with a basic impulse level (BIL) of [95 at 14.4 kV] [110 at 35 kV]. Access door shall be mechanically interlocked with a switch mechanism. Switch enclosure shall be 12-gage 2.7 millimeter minimum sheet steel. Switchgear to switch connections shall prevent ground transmission to the switch.

Provision shall be made for terminating underground cables and for bus connections to the primary of the transformer transition box. Flexible connections shall be used between primary potheads and the interrupter switch with adequate bracing provided for short-circuit stresses.

Interrupter switch shall be Kirk key interlocked with the low-voltage main circuit breaker to prevent interrupting load current. Switch shall have provisions for padlocking in the open and closed positions. Open and closed switch positions shall be clearly and permanently marked on the outside of the enclosure. A mechanical indicator shall show the switch position.

Switch shall have provision to add electrical operation with auxiliary contacts, and shall be [two-position, single-throw] [duplex dual feeders] [selector type].

Interrupter switchgear shall be equipped with three current limiting [CLE type] [RBA boric acid] power fuses capable of interrupting the available short-circuit current with switch carrying full load rated current. A mechanical interlock shall be provided to prevent access to the power fuses when the interrupter switch is closed.

2.6.2 Instruments and Instrument Transformers

Indicating instruments, protective relays, current and potential transformers, instrument transfer switches, control-power transformers, and the like shall conform to the applicable requirements of Section 16286, "Overcurrent Protective Devices."

2.6.3 Surge Arresters

Surge arresters shall be the station type and shall conform to Section 16288, "Surge Arresters."

2.6.4 Control-Power Circuit Over-Current Protection

Branch circuit breakers shall provide circuit overload protection to compartment heaters, lights, convenience outlets, transformer fans, automatic load-tap changers, and other substation devices.

2.6.5 Station Battery

[Batteries for 125-volt dc control circuits shall be the 60-cell, lead-acid or Nickel-Cadmium type with pasted-plate assembly in sealed plastic or glass cases, complete with intercell connectors, electrolyte, portable hydrometer, and thermometer. Battery shall provide 125-volt dc for operation of the breaker shunt-trip coils and solenoid-closing coils.]

[Batteries for 24-volt dc control circuits shall be the 12-cell, lead-acid or nickel-cadmium type with pasted-plate assembly in sealed plastic or glass cases, complete with intercell connectors, electrolyte, portable hydrometer, and thermometer. Battery shall provide 24-volt dc for operation of the breaker shunt-trip coils.] Direct current circuit shall be ungrounded and provided with overcurrent protection. Battery racks shall be steel, treated and coated to resist corrosion by electrolyte, and shall be earthquake-resistant construction.

Battery charger shall be fully automatic with overcurrent protection and adjustable high-charge and trickle-charge rates. Charger shall maintain the battery at full charge under normal operating conditions and shall recharge the depleted battery in not more than 8 hours. Battery charger shall be connected to the load side of the control-power transformer and shall be isolated from the source and ground through a two-winding dry-type stepdown transformer. Battery charger shall be equipped with an ammeter to indicate the charging rate, a voltmeter, cut-off switch, variable resistor, and full-wave rectifier.

Alternating current circuit breaker control shall be provided by a separate control system with a separate transformer at 240 volts, 60-hertz, single-phase. An automatic transfer control power contactor and an automatic under-voltage trip shall be provided.

2.6.6 Automatic/Manual Transfer Switch

Automatic manual transfer switch shall be the rotary snap-action type with silver-plated contacts. Transfer switch shall be a manually operated two-position device designed to interrupt the automatic transfer and re-transfer features of the system when the transfer switch is in the manual position. Switch shall permit the transfer of all load to either transformer in the transformer section without a service interruption when the transfer switch is in the automatic position. Provision shall be made for matching the taps on both transformers before transferring the load when automatic tap-changing equipment is provided.

2.6.7 Control-Power Circuit Contactor

Contactor for automatic transfer of control power shall be designed for 120/240-volt, single-phase, 60-hertz service with current rating as indicated. Contactor shall be the open type, two-pole, double-throw with

solid neutral connections and shall automatically transfer its load circuits to the alternate power supply upon loss of power in the normal supply. Device shall be electrically operated and mechanically held and shall obtain its operating current from the source to which the load is transferred. Contactors for automatic transfer of control power shall be suitable for installation in metal-clad switchgear.

2.6.8 Current-Limiting Reactors

Current-limiting reactors shall be air-core, dry-type, self-cooled, 80-degree C temperature rise, three-phase, 60-hertz devices in accordance with ANSI C57.99.

Reactor assembly shall include three insulated-copper single-phase coils, vertically mounted, rigidly braced, supported and secured to the foundation. Coil assembly shall be insulated between phases and supported above the foundation with porcelain insulators. Insulators shall conform to ANSI C29.10.

Reactor enclosure shall be constructed with side covers insulated from vertical framing members and vertical framing members insulated from each other to minimize magnetic saturation and eddy-current heating by reactor flux. Enclosure shall be insulated from either front or back floor channels to avoid a closed short-circuited turn below the reactor. Hinges on doors shall be insulated. Enclosure shall not be bridged electrically with conduit, a ground bus, or other conducting material.

Side clearances within the enclosure shall not be less than one-third the outside diameter of the coil assembly. Top clearances within the enclosure shall not be less than one-half the outside diameter of the coil assembly.

Magnetic shields shall be provided on the near sides of adjacent compartments to prevent eddy-current heating in adjacent apparatus.

Leads shall be taken off the coils in the direction of the flux stream with flexible connections to side wall seal-off bushings.

[Current-limiting reactors with 3-percent reactance or less shall have a mechanical and thermal short-time current rating not less than $33\frac{1}{3}$]

[Current-limiting reactors with more than 3-percent reactance shall have a mechanical and thermal short-time current rating not less than the ratio of 100 to the percent reactance of the reactor] times the continuous-current rating of the reactor at 105 percent of the rated voltage for 3-seconds under short-circuit conditions.

2.6.9 Neutral Grounding Resistors

Neutral grounding resistors shall consist of one or more indoor load resistor elements vertically mounted in auxiliary compartments of metal-clad switchgear assemblies for the effective grounding of 2,300-, 6,900-, 13,200-, and 13,800-volt, three-phase, 60-hertz power-distribution systems in accordance with IEEE Std 32.

Resistor elements shall be an assembly of heavy-duty cast-iron grids of uniform thickness transversely mounted on metal tie rods to end frames designed for stacking. Cast-iron grids shall be insulated from tie rods, end frames, and from each other with insulation material consisting entirely of mica, porcelain, glass, quartz, or similar inorganic material.

Cast-iron grids in each element and between elements shall be electrically connected in series to form an electrical path between the neutral and ground-terminal connections. Entire assembly of resistor elements shall be supported above the foundation with porcelain insulators.

Neutral bus and ground connections to grounding resistors shall be made with suitably braced, full-capacity, fully isolated conductors.

Standard insulation class of neutral and ground-terminal bushings and supporting insulators shall be the same as the circuit-voltage class of the distribution system.

Voltage rating of grounding resistors shall not be less than the phase-to-neutral voltage of the power-distribution system. Grounding resistors shall be capable of carrying 2,000 amperes for 10 seconds at the rated voltage without exceeding a temperature rise of 500 degrees C above an ambient temperature of 25 degrees C.

2.6.10 Service and Maintenance Devices

The following service and maintenance devices shall be included as a part of the substation:

- A manual handle for operating the air circuit breaker isolating mechanism

- A removable manual maintenance closing device for air circuit breakers

- A transfer truck for air circuit breakers

- Facilities for operating air circuit breakers in the test or removed position

- Facilities for withdrawing air circuit breakers for inspection or maintenance

- Test plugs and cable for meters and relays

2.6.11 Load-Break Oil Switches

Load-break oil switch shall consist of a load-break disconnect switch or switches contained in a removable oil-filled compartment enclosing the side wall bushings of the transformer and equipped with single- or multiple-conductor potheads for bottom connection to underground power cables.

Enclosure shall be constructed of welded steel plate with bolted and gasketed flange connections and covers. Exposed bolts, nuts, and studs shall be silicon bronze or corrosion-resistant steel.

Sealed cable entrance fittings shall be cast brass with wiping sleeves for lead-covered cables and cast iron watertight stuffing boxes for nonlead cables. Potheads shall be suitable for single- or multiple-conductor cables.

Oil-immersed disconnect switch or switches shall be three pole with two or three positions, as indicated, for single- or double-throw operation or a combination thereof.

External manually operated switch handle or handles shall indicate the position of the switch and shall provide for padlocking in each position on each operating handle.

Switch enclosure shall be equipped with viewing windows that will permit visual inspection of the switch contacts, oil-level gage, ground lugs, and pipe plugs for filling, closing, and draining operations.

Entire assembly shall be watertight, oiltight, and airtight and shall be suitable for operation under extreme weather conditions. After assembly and before delivery, switch tanks shall be pressure-tested under water by the manufacturer by applying an air pressure of 5 psi 34 kilopascal for 15 minutes. Switch tanks shall be pressure-tested after installation and before filling with oil by applying an air pressure of 5 psi 34 kilopascal for 15 minutes and visually checking for leaks by applying soapy water to joints.

Load-break oil switches shall be capable of withstanding the tests specified in IEEE Std 48.

Insulating oil shall conform to ASTM D 3487 with inhibitor.

2.6.12 Oil Switch and Cable Termination Compartments

Combination oil-switch and cable-termination compartments shall consist of an oil switch and cable terminations in a one-piece, two-compartment, removable weatherproof enclosure designed for side-wall mounting to the transformer and bottom connection to underground cables in accordance with ANSI C57.12.40.

Enclosure shall be constructed of welded steel plate with bolted and gasketed flange connections and covers. Exposed bolts, nuts, and studs shall be silicon bronze or corrosion-resistant steel.

Primary winding terminals of the transformer shall be brought through the wall of the tank into an oil-filled compartment containing an externally operable three-pole, three-position, quick-break disconnecting and grounding switch capable of interrupting the transformer magnetizing current. Electrical characteristics of the switch shall be in accordance with ANSI C57.12.40.

External manually operated switch handle shall indicate the position of the switch and shall have provisions for padlocking in each position of the operating handle. Switch shall be Kirk key-interlocked with the transformer secondary main breaker to prevent operation under load.

Switch compartment shall be equipped with viewing windows that will permit visual inspection of the switch contacts, oil-level gage, pressure-relief diaphragm, ground lug, and pipe plugs for filling, closing, and draining operations. Insulating oil shall conform to ASTM D 3487 with inhibitor.

Compound-filled cable termination compartment located in the lower part of the enclosure shall be designed for terminating underground cables of the size, type, and voltage rating indicated. Lower terminals of the high-voltage bushings through the common wall between compartments shall be provided with lugs for connection to underground cables. Bottoms of the lugs shall not be less than 20-inches 510 millimeter above the bottom of the compartment.

2.6.13 Space Heaters

Each section of the secondary unit substation, including the primary switch, and the secondary switchgear assemblies, shall be equipped with space heaters to provide approximately 4 watts per square foot 40 watts per square meter of outer surface area. Heaters shall be such that the power density does not exceed 4 watts per square inch 4 watts per 650 square millimeter of heater element surface. Heaters shall be rated at 240 volts for connection to 120 volts.

Heaters shall be located at the lowest portion of each space to be heated. Terminals shall be covered. Thermostats shall be used to regulate the temperature.

All heaters shall be installed and operable at the time of shipment so that the heaters can be operated immediately upon arrival at the site, during storage, or before installation. Connection locations shall be marked prominently on drawings and shipping covers and shall have temporary leads for storage operation. Leads shall be easily accessible without having to remove shipping protection.

2.6.14 Protective Relays and Devices

**NOTE: Additional requirements are specified in
Section 16286, "Overcurrent Protective Devices."**

Protective relays shall be semiflush-mounted, drawout type with built-in test facilities. Relays connecting to current transformer secondaries shall automatically short circuit the secondary when in the drawout position.

2.7 WEATHERPROOF ENCLOSURES WITHOUT MAINTENANCE AISLES

**NOTE: Delete this part when a weatherproof
enclosure with a maintenance shelter is required.
If the project requires protection against dust,
sand, etc., add provisions for filters.**

Weatherproof protection for switchgear assemblies without enclosed maintenance aisles shall consist of switchgear and auxiliary equipment compartments, as herein specified, protected with weatherproof ventilated front and rear hinged doors, base and roof sections, roof seam covers, finishing strips, and end trims.

Front and rear access doors shall be flanged and shall close against rubber or similar weatherproof gasketing material. Ventilated openings shall be provided with filtered louvers and screened vents. Doors shall be equipped with latch, stops, and door-locking mechanisms.

Roof section shall be unit construction with a removable sloping cover and overhanging roof drip edges. Base section shall be unit construction and shall support switchgear assemblies 6-inches 150 millimeter above the concrete foundation.

Each switchgear compartment shall include a removable steel floor plate

which shall be drilled for conduit and cable during installation. Floor of the switchgear assembly shall be undercoated with a heavy rubberized protective sealing material at least 1/32-inch 0.8 millimeter thick.

Each compartment shall be equipped with electric space heaters to minimize condensation, interior lighting outlets, utility outlets, and circuit overload protection.

2.8 WEATHERPROOF ENCLOSURES WITH MAINTENANCE AISLES

NOTE: Delete the heading and the following paragraphs when weatherproof protection without maintenance shelters is required. If project requires protection against dust, sand, etc., add provisions for filters.

Weatherproof enclosures for switchgear assemblies with enclosed maintenance aisles shall be constructed in accordance with IEEE C37.20.1 and shall consist of indoor switchgear and auxiliary compartments installed in a sheet metal weatherproof housing, with operating aisle space for the inspection, operation, and maintenance of equipment.

Weatherproof enclosure shall consist of framed sheet metal roof sections; front, rear, and side panels; [front] [side] hinged doors, rear hinged doors, floor plates, and supporting floor channels. Ventilated access doors shall be located as indicated, with safety latches conforming to FS FF-H-106, that permit quick release from the inside even when the doors are padlocked on the outside. Doors shall be flanged and shall close against rubber of similar weatherproof gasketing material. Ventilated openings shall be provided with filtered louvers and screened vents.

Each switchgear compartment shall include a removable steel floor plate which shall be drilled for conduit and cable during installation. Floor of the weatherproof enclosure shall be undercoated with a heavy rubberized protective sealing material at least 1/32-inch 0.8 millimeter thick. Asbestos sealing material shall not be used.

Weatherproof enclosures shall be equipped with electric space heaters (to minimize condensation), interior lighting, and utility outlets with circuit overload protection.

Structural members and exterior coverings shall be constructed in accordance with AISI SG-671.

Hot-rolled steel sheet, plate, and strip, 1/8-inch 3.2 millimeter thick and thicker, shall conform to the requirements of ASTM A 36/A 36M. Hot-rolled steel sheet and strip less than 1/8-inch 3.2 millimeter thick shall conform to the requirements of ASTM A 570/A 570M, Grade 36.

Enclosure shall be clear-span shed-roof design with a roof slope of not less than 1 inch in 12 inches of horizontal run 1 vertical to 12 horizontal. Structure shall be designed to withstand a roof live load of not less than 20 pounds per square foot 100 kilograms per square meter and wind pressures of not less than 35 pounds per square foot 170 kilograms per square meter. Interior floor plates and supporting floor channels shall be designed to withstand live loads of 250 pounds per square foot 1200 kilograms per square meter with deflections not exceeding 1/240 of the clear span.

2.9 POST BUSHINGS FOR WEATHERPROOF ENCLOSURES

Where indicated, post bushings shall be provided to accommodate overhead primary service. Characteristics and dimensions of bushings shall be in accordance with ANSI C57.19.01.

2.10 AUTOMATIC TRANSFER SWITCH OPERATION AND DEVICES

Provision shall be made for the automatic transfer of load on loss of voltage, low voltage, single phasing, reverse phase rotation of either source, and the automatic retransfer of load upon restoration of normal service without a service interruption. Under normal operation, both main secondary breakers will be closed with the main bus tie breaker open and the automatic/manual transfer control switch in the automatic position and each source of supply will be energized and carrying load.

Main and bus tie breakers shall be electrically operated with remote pushbutton controls electrically interlocked so that only two of the three breakers may be closed by operation of the respective breaker-closing mechanisms when the automatic/manual transfer control switch is in the manual position.

Main secondary breaker compartments shall include undervoltage and phase-sequence relays with adjustable time-delay between 30 and 200 cycles.

Auxiliary relays shall automatically open the proper main secondary breaker and close the main bus tie breaker under fault conditions. Provisions shall be included for the automatic reclosing of the main secondary breakers before opening the main bus tie breaker when normal service is restored.

Lockout relays shall prevent automatic transfer of load from undervoltage caused by overload or transient conditions. Lockout relay controls shall be connected into the closing circuit of the main tie breaker to prevent operation under lockout conditions and shall be the hand-reset type.

Main bus tie breaker compartment shall include an automatic/manual transfer switch which shall disconnect the automatic transfer features when in the manual position. Main secondary and bus tie breakers shall be manually inoperable when the automatic/manual transfer control switch is in the automatic position.

A bypass switch shall be provided to permit manual momentary paralleling of the two sources of supply in restoring normal service without interruption.

Main secondary and bus tie breakers shall be manually operable when the automatic/manual transfer control switch is in the manual position.

A contactor shall be provided for the automatic transfer of control power. Each of the control power transformers shall be capable of furnishing power through the selective contactor for the bus tie breaker, all feeder breakers, compartment heaters, interior lighting, utility outlets, battery chargers, and other miscellaneous equipment.

Secondary switchgear assembly or assemblies shall be supplied from two separate sources, with each source normally carrying load as indicated. Under normal operation, both main secondary breakers will be closed with the main bus tie breaker open. Two sources of supply shall not be operated

in parallel.

2.11 PAINTING

Paint materials shall be in accordance with referenced standards.

NOTE: For all outdoor applications and all indoor applications in a harsh environment refer to Section 09960, "High Performance Coatings." High performance coatings are specified for all outdoor applications because ultraviolet radiation will break down most standard coatings, causing a phenomena known as chalking, which is the first stage of the corrosion process. For additional information contact The Coatings Industry Alliance, specific suppliers such as Keeler and Long and PPG, and NACE International (NACE).

After fabrication, all exposed ferrous metal surfaces of the primary-unit substation and component equipment shall be cleaned and painted. The primary-unit substation shall have the standard finish by the manufacturer when used for most indoor installations. For harsh indoor environments (any area subjected to chemical and/or abrasive action), and all outdoor installations, refer to Section 09960, "High Performance Coatings."

2.12 FACTORY TESTING

Factory tests on transformers and switchgear assemblies shall be made in accordance with the applicable provisions of the referenced standards.

Tests on transformers shall include insulation-resistance tests of the windings, ratio tests, polarity and phase rotation tests, no-load loss at rated voltage, excitation current at rated voltage, impedance voltage load loss tests at rated current, insulation power factor tests, impulse tests, temperature rise test, short circuit test, oil power factor tests, oil acidity tests, water-in-oil (Karl Fischer tests), dissolved gas analysis, sound tests, dielectric tests, and bushing tests. Tests shall be conducted in accordance with IEEE C57.12.90 and IEEE C57.12.00, Table 16.

Tests on switchgear assemblies shall include mechanical operational test, electrical operation and control-wiring tests, relaying and metering circuit performance tests, and dielectric tests. Tests shall be conducted in accordance with IEEE Std 4.

2.13 Factory Documentation

Drawings of the fabrication and assembly details shall be submitted for the following items; transformer tanks, transformer cores, transformer coils, bushings, switchgear components, incoming and outgoing sections, and accessories.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installation shall conform to IEEE C2 and NFPA 70.

Complete assembly shall be electrically and mechanically connected together at the site from coordinated subassemblies shipped in complete sections from the manufacturer. Installation shall be carefully aligned, leveled, and secured to the concrete foundation [in accordance with the manufacturer's written instructions.] [under the direct supervision of the equipment manufacturer's authorized technical representative who shall be given full authority in the determination of installation procedures. Cost of such service shall be included as a part of this contract.]

Primary unit substation shall be provided with an earth ground grid resistance pad as shown on the drawings. Substation resistance to ground shall not exceed the following values:

Below 5,000 kVA 5 ohms

5,000 kVA and above 3 ohms

Noncurrent-carrying parts and enclosures of the substation shall be bonded together and grounded to the substation ground pad with a maximum resistance to ground of 20 ohms. Connections shall be exothermic welded in accordance with UL 467.

Switchgear ground pad connection to the switchgear frame shall not be less than No. 4/0 AWG cable or copper bus bar equal to No. 4/0 AWG (12 millimeter diameter) cable, current rating.

Installation Drawings shall be submitted for the primary unit substation. Drawings shall include complete details of equipment layout and design.

3.2 FIELD TESTING

The following transformer tests shall be performed in the presence of the Contracting Officer:

- Turns Ratio Test
- Phase Rotation Test
- Insulation Resistance Tests
- Insulation Power Factor Tests
- Winding Excitation Tests
- Insulating Oil Tests

Transformer windings of primary-unit substations shall be subjected to insulation-resistance and insulation power factor tests after the installation is completed and ready for operation.

Test equipment, labor, and technical assistance shall be provided to perform the electrical acceptance tests, as herein specified.

Current-transformer secondary windings involved in the test shall be shorted and grounded. Potential- and control-power-transformer fuses involved in the test shall be removed and the compartment grounded.

Primary windings of the transformer shall be disconnected from the power supply, and the secondary windings of the transformer shall be grounded before conducting insulation and high voltage tests on the primary windings.

Secondary windings of the transformer shall be disconnected from the secondary feeder cables/bus, and the primary of the transformer grounded before conducting insulation and high voltage tests on secondary windings.

Windings of the transformer shall be given an insulation-resistance tests with a 5,000-volt insulation-resistance test set.

Readings shall be recorded every 15 seconds for the first minute and every minute thereafter for 10 minutes. Resistance between phase conductors and ground shall be no less than 125 megohms.

Upon satisfactory completion of the insulation resistance test the transformer windings shall be given a insulation power factor test and an excitation test. Maximum acceptable power factor is .5 percent. Excitation results will vary due to the amount of iron and copper in the windings and are used for baselines only.

The transformer shall then be given a turns ratio test. Readings shall be within 1/2 percent of each other.

Upon satisfactory completion of the above electrical tests the transformer shall then be given the following oil tests in accordance with IEEE Std 62 and ASTM D 3612: power factor, neutralization number, Karl Fisher, Dissolved gas analysis, and dielectric. Results shall be as follows:

| | |
|----------------------------|---------------------------------------|
| Power Factor | less than 0.5 percent at 20 degrees C |
| Karl Fisher | less than 25 ppm at 20 degrees C |
| Neutralization Number | less than 0.03 gm KOH/ml |
| Dielectric | greater than 28KV |
| Dissolved Gas Combustibles | less than 1000 ppm total |

Upon satisfactory completion of the transformer tests the main bus shall be subjected to an insulation resistance and high voltage DC (hi-pot) withstand test.

Insulation resistance test voltage shall be 5000 volts for switchgear 4160 volts and above and 1000 volts for switchgear below 4160 volts. Test voltage shall be applied to the main bus for not less than 5 minutes and until 3 equal consecutive readings, 1 minute apart, are obtained. Readings shall be recorded every 30 seconds during the first 2 minutes and every minute thereafter. Minimum acceptable resistance shall be 100 megohms.

Upon satisfactory completion of the insulation resistance test the main bus shall be given a high-pot test. Test voltage shall be equal to [100 percent for 60 Hz] [75 percent for dc] of the values shown in IEEE C37.20.1 and IEEE C37.20.2 for metal-clad switchgear and metal-enclosed low-voltage power-circuit-breaker switchgear. Test shall be applied for 1 minute.

Weatherproof enclosure and switchgear assembly shall be subjected to a weatherproofing test conducted at the site in the presence of the Contracting Officer in accordance with IEEE C37.20.1.

Final acceptance will depend upon the satisfactory performance of the equipment under test. Substation shall not be energized until the recorded test data have been approved by the Contracting Officer. Final test reports shall be provided to the Contracting Officer. Reports shall have a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

3.3 RELAY SETTINGS AND TESTS

3.3.1 Coordination

All circuit-interrupting devices shall be properly coordinated before the substation is energized. Protective relays shall be thoroughly inspected and adjusted at the site in the presence of and at the discretion of the Contracting Officer.

Trip ratings for all protective relays will be determined by the Contracting Officer and will be set by the manufacturer or the manufacturer's representative in the presence of the Contracting Officer at the construction site.

3.3.2 System Coordinator

Services of a professional electrical engineer who specializes in relays and coordinating systems associated with electric power apparatus for the manufacturer of the equipment shall coordinate circuit-interrupting devices before the substation is energized. Duties and responsibilities of the specialist shall include the following work:

Preliminary survey and system coordination study:

Equipment shall be inspected and the intended function of each circuit-interrupting device and the manner in which it is connected shall be determined to provide a properly coordinated electrical power system under normal load and fault conditions.

Wiring diagrams furnished by the manufacturer shall be inspected and compared with actual connections of the equipment to verify that each device is properly connected to perform its intended function.

Necessary short-circuit calculations shall be reviewed to determine the minimum and maximum values of short-circuit current for faults anywhere in the system. Values of fault current to be expected at each protective device shown on the one-line diagrams shall be reviewed.

System or substation designer shall perform the following:

Time-current curves shall be plotted on a single sheet of graph paper for those devices that are to operate selectively in series with each other, using a common current scale with current ratings at the lowest voltage level. Curves shall be plotted progressively as each circuit is studied, starting with the device furthest from the source. Each curve on the graph shall include the tolerance band and shall show the degree of coordination with each successive device. Adjustable and non-adjustable protective devices shall be coordinated to operate on the minimum current that will permit distinguishing between fault and load current in a minimum amount of time.

Time and current settings shall be selected for the adjustable devices that will operate in sequence with the nonadjustable devices to isolate a fault with a minimum of disturbance to the unfaulted portion of the system.

After completion of the preliminary survey and coordination study of the system, the following documents shall be prepared by the Contractor and approved by the Contracting Officer before proceeding with the work:

One-line diagram of electrical equipment and system

Short-circuit calculations and a table of short-circuit fault currents at critical points in the electrical system

Time/current coordination curves

Table of recommended relay settings

3.3.3 Preliminary Inspection, Relay Setting, and Tests

Preliminary inspection of electrical equipment shall proceed; relay settings and tests, by a certified testing lab, and shall be made only after the preliminary survey and system coordination survey have been completed. Preliminary inspection, relay settings, and tests shall be as follows:

Equipment shall be inspected for damage or maladjustment caused by shipment or installation. Wedges, ties, blocks, and other packing material installed by the manufacturer to prevent damage in shipment shall be removed.

Protective relays, auxiliary relays, trip coils, trip circuit seal-in and target coils, fuses, and instrument transformers shall be verified to be of the proper type and range.

Electrical continuity tests shall be performed on current, potential, and control circuits.

Ratio and polarity tests shall be performed on current and potential transformers.

Insulation tests shall be performed on relays, wiring, instrument transformer secondary windings, and instruments.

Each adjustable relay shall be removed from its case and calibrated separately as an instrument, using a variable alternating-current source and an accurate timing device. This procedure shall verify that the relay has not been damaged in shipment and that it will perform in accordance with previously prepared time-current coordination curves at specified current tap and time dial settings.

With the relay disconnected and the main current transformer effectively open, a test current shall be applied to the remainder of the secondary circuit to detect any open- or short circuit connections.

Relays shall then be reinstalled and connected into their current transformer secondary and control circuits.

Any defects in electrical equipment, protective devices, wiring, or other conditions that will prevent complete coordination and the successful operation of equipment shall be reported to the Contracting Officer before proceeding with the work.

After the installation has been thoroughly tested and certified to be in

satisfactory condition, with relays calibrated and adjusted to the proper current tap and time dial setting, the Contractor shall request permission to energize the equipment at system voltage for final testing.

3.4 ENERGIZING THE PRIMARY UNIT SUBSTATION

NOTE: If required by the project, the following
paragraphs should be replaced with the statement
"Primary-unit substation will be energized by
Government personnel."

Primary unit substation shall not be energized until it is completely installed and ready for operation. Field testing shall have been conducted and approved by the Contracting Officer.

Using an ammeter, voltmeter, and wattmeter or phase-angle meter, the values and polarities of voltage and current shall be measured and compared with those expected in the various relay circuits. Contact positions of directional elements and voltage relays shall be inspected and as noted.

After inspection and satisfactory tests have been completed on all active relay circuits under a no-load condition, each relay shall be given an operational test with diverted load currents or simulated ground faults.

Following successful operation of all relays and equipment under normal and simulated fault conditions, circuits shall be restored to the normal operating condition and left ready for service.

A report shall be prepared with records of connections, electrical constants, settings, test values, operating performance, and failures or weaknesses found on test.

Tests and procedures for testing shall be in accordance with the manufacturer's recommendations, as approved by the Contracting Officer.

-- End of Section --